Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

COSMO applications on heterogeneous architectures

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Why using the COSMO-GPU version

- Developments from the COSMO priority project POMPA
- COSMO is 3x faster on GPUs
- Easier to get allocation time on large heterogenous systems (e.g. Piz Daint)
- Even on CPU-only system the new version is faster (using the c++ dycore)
- Possibility to run in single precision

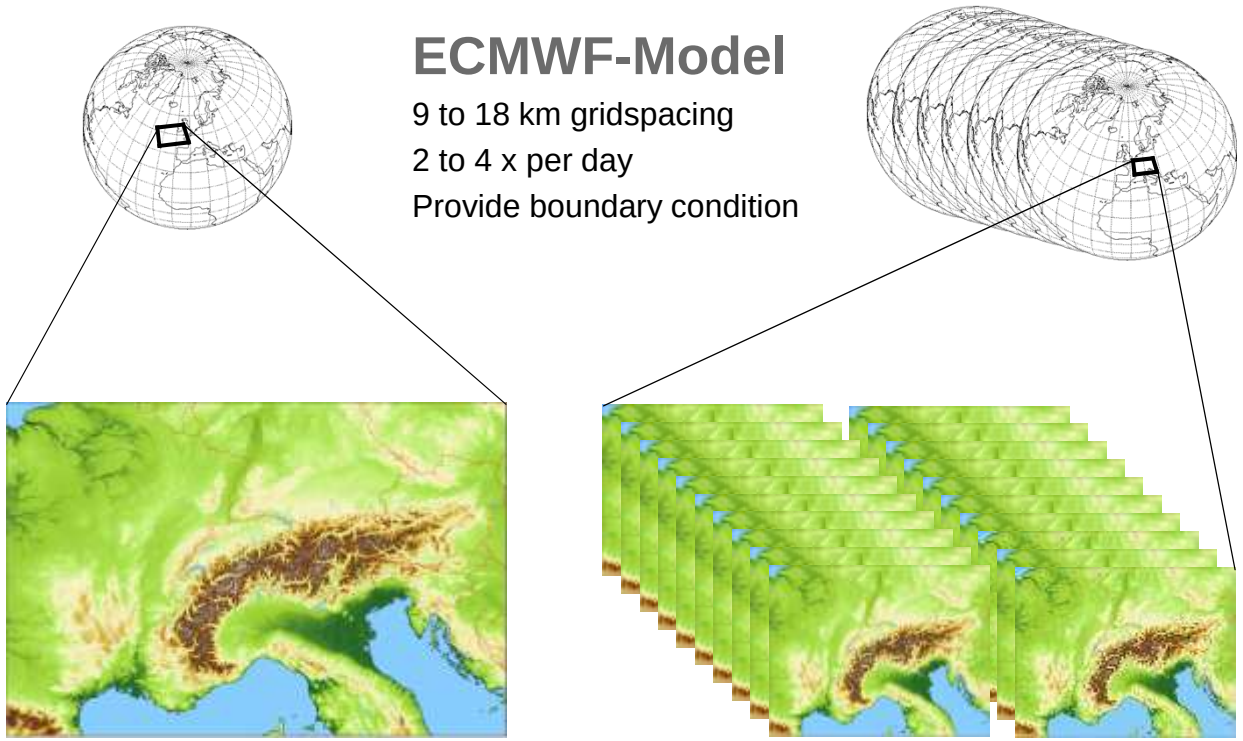
Piz Daint, at CSCS, Switzerland, fastest machine in Europe, is GPU based

4 Applications of POMPA project developments

- MeteoSwiss operational forecast system
- COSMO CALMO project
- COSMO LEPs
- European-scale multi-year convection-resolving climate simulations

Operational Forecast MeteoSwiss

- COSMO-1 (1 km high resolution) and COSMO-E (ensemble)
- Running on GPU, in single (Forecast) and double precision (Analysis)
- About **4x** was gained by acquiring a GPU system (Piz Kesch)



ECMWF-Model

9 to 18 km gridspacing
2 to 4 x per day
Provide boundary condition

COSMO-1

1.1 km gridspacing
8 x per day
1 to 2 d forecast

(Since April 2016)

COSMO-E

2.2 km gridspacing
2 x per day
5 d forecast
21 members

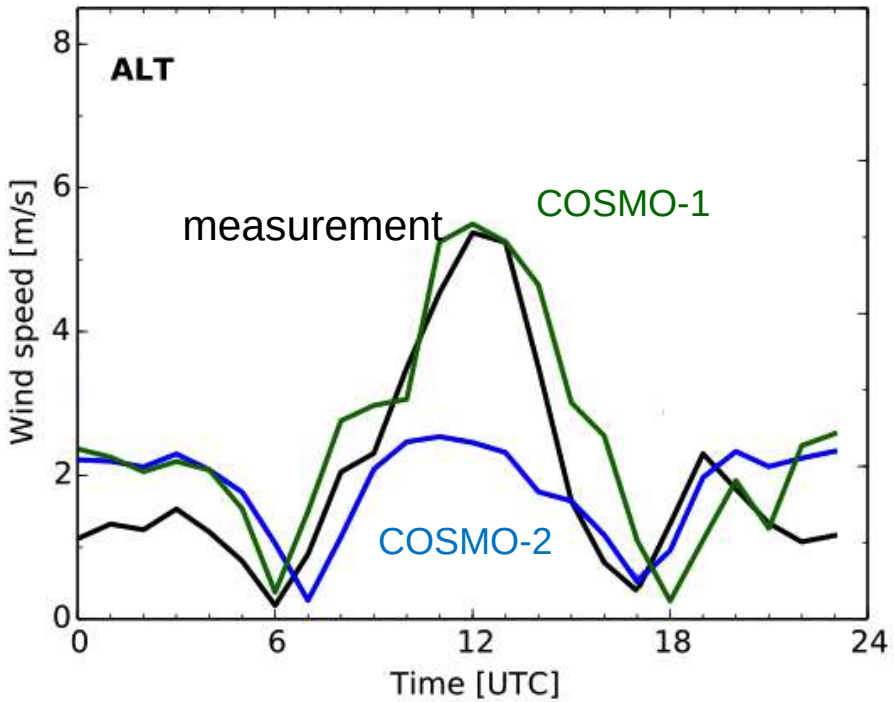
(Operational ince Mai 2016)

Ensemble data assimilation: LETKF

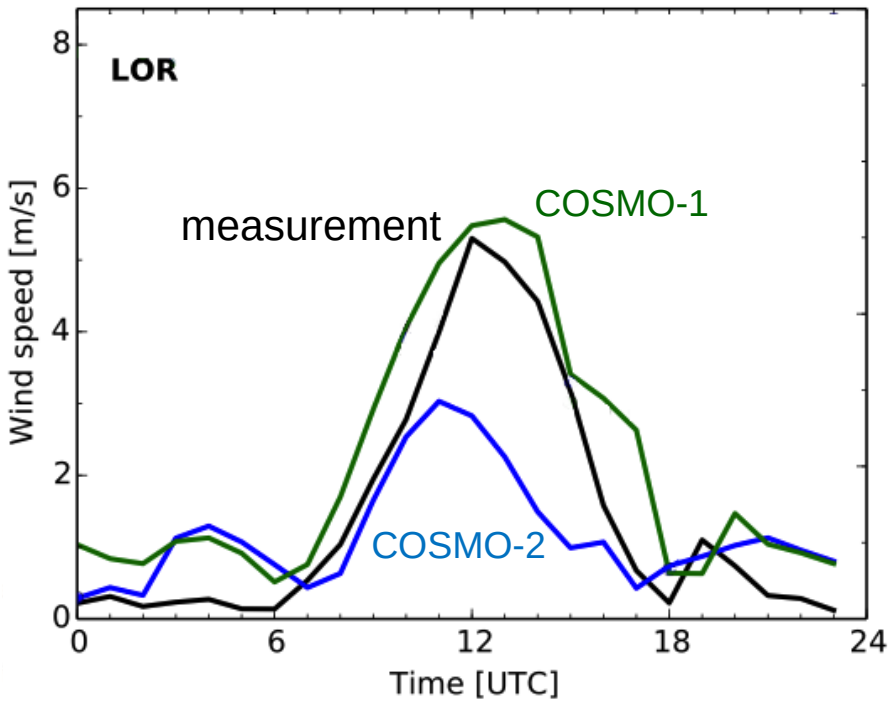
Benefit of the higher resolution

(18 days: 9. – 27.7.2006)

Altdorf (Reuss valley)

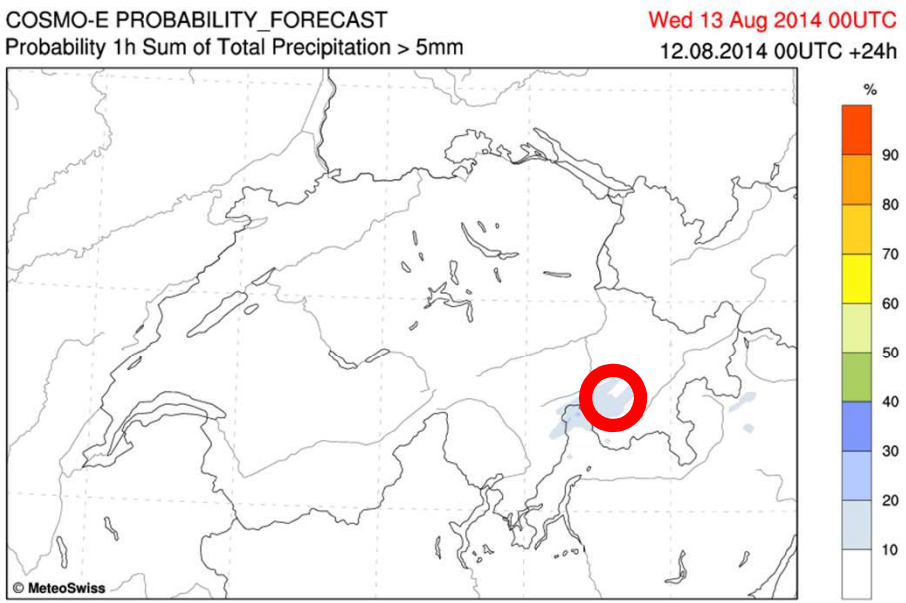


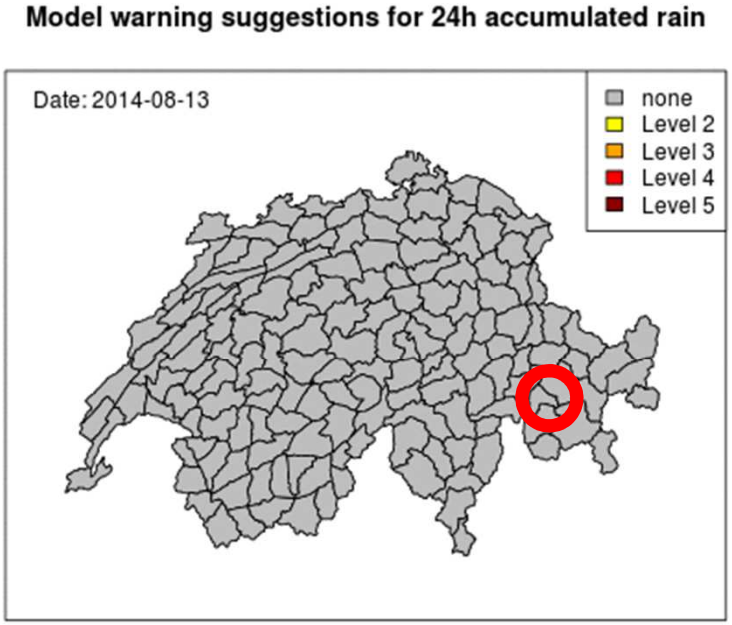
Lodrino (Leventina)



Benefit of ensemble for warnings

Example: Landslide affecting railway in the Alps, 13. 8. 2014



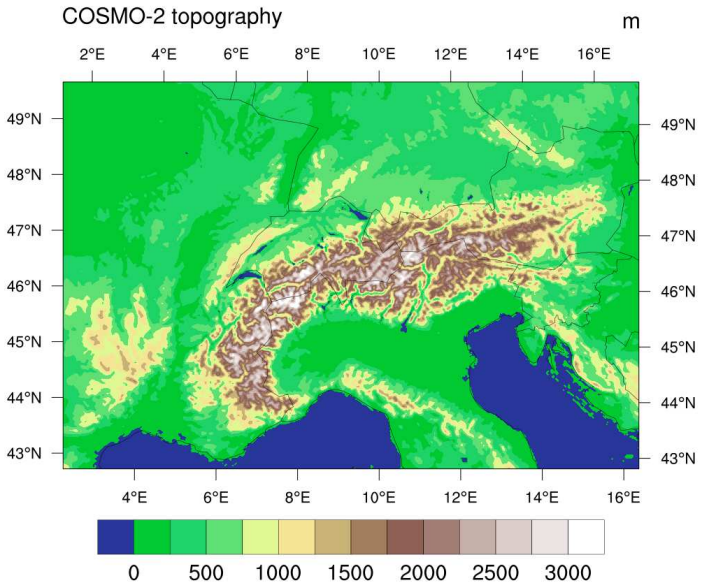


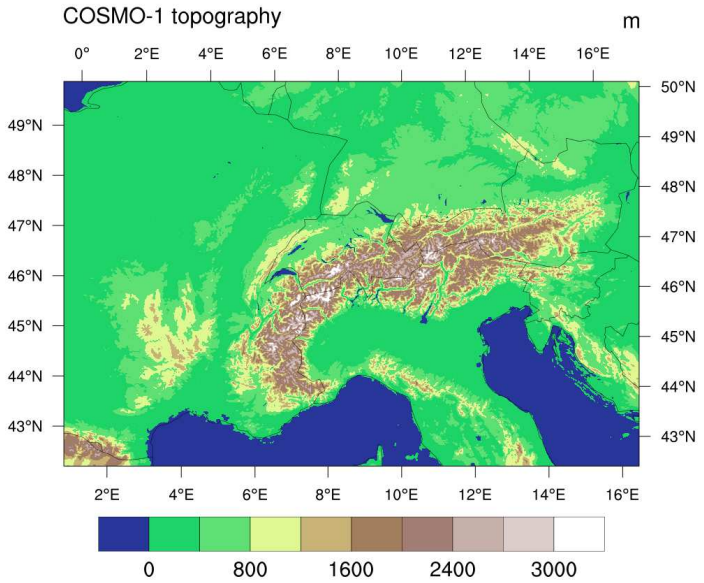
Probabilistic rain forecast
1h Sum > 5mm from COSMO-E

Automatic warning proposals
derived from COSMO-E

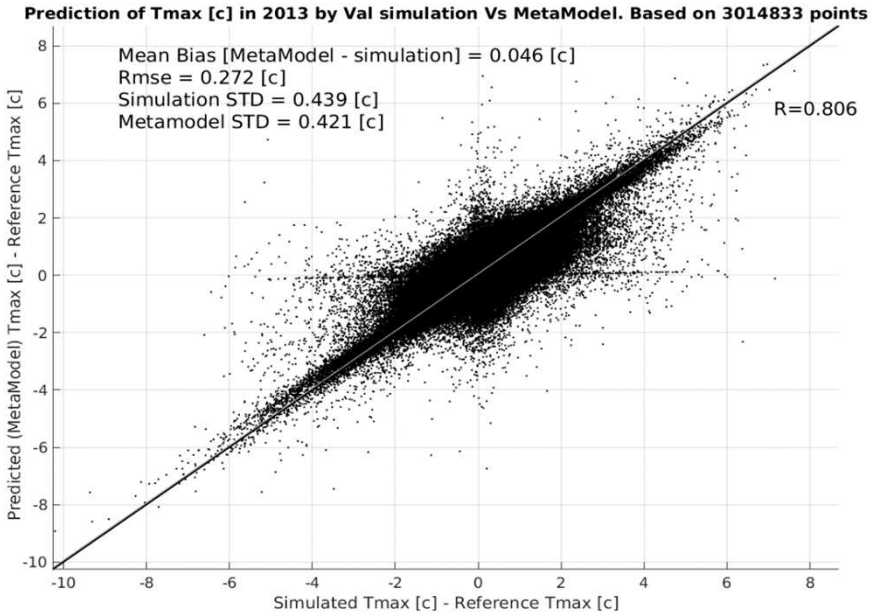
CALMO project

- Provide an objective methodology for tuning NWP models parameters, based on work from Bellprat et al, (2012)
- Usage of the GPU version for COSMO-2 and COSMO-1 configurations
- More than 270000 node hours used on PiZ Daint at CSCS
- More than 80TB generated and stored data

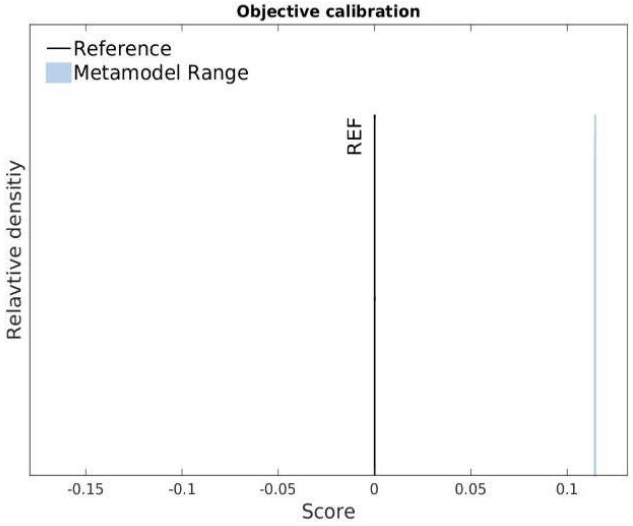




Accuracy of the MM. MM fitting for Tmax with correlation coefficient R=0.806 for COSMO-2

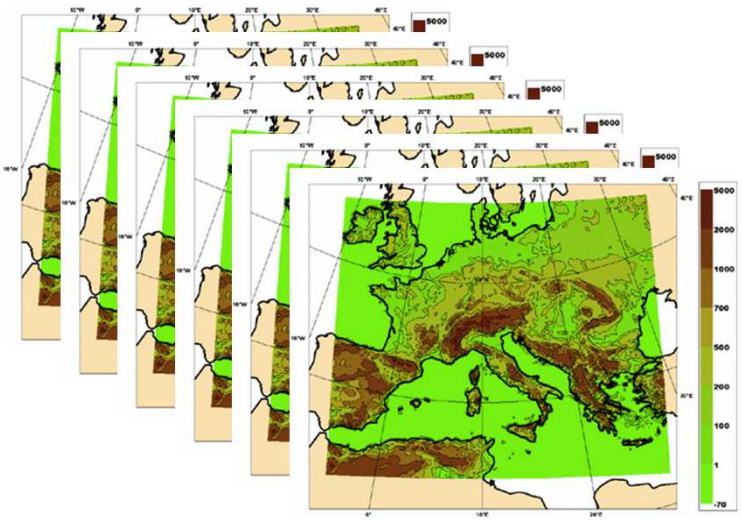


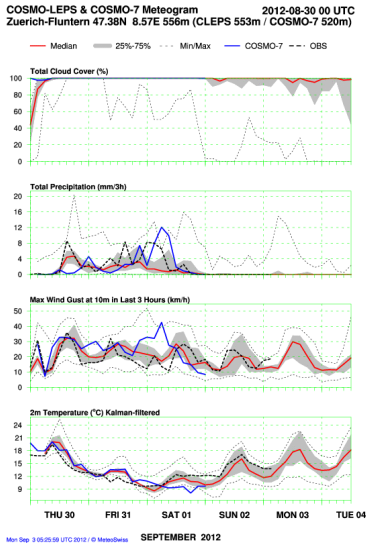
Final score distribution together with the score of the reference (REF) simulation for COSMO-1



COSMO LEPS

Ensemble system from COSMO consortium run at ECMWF



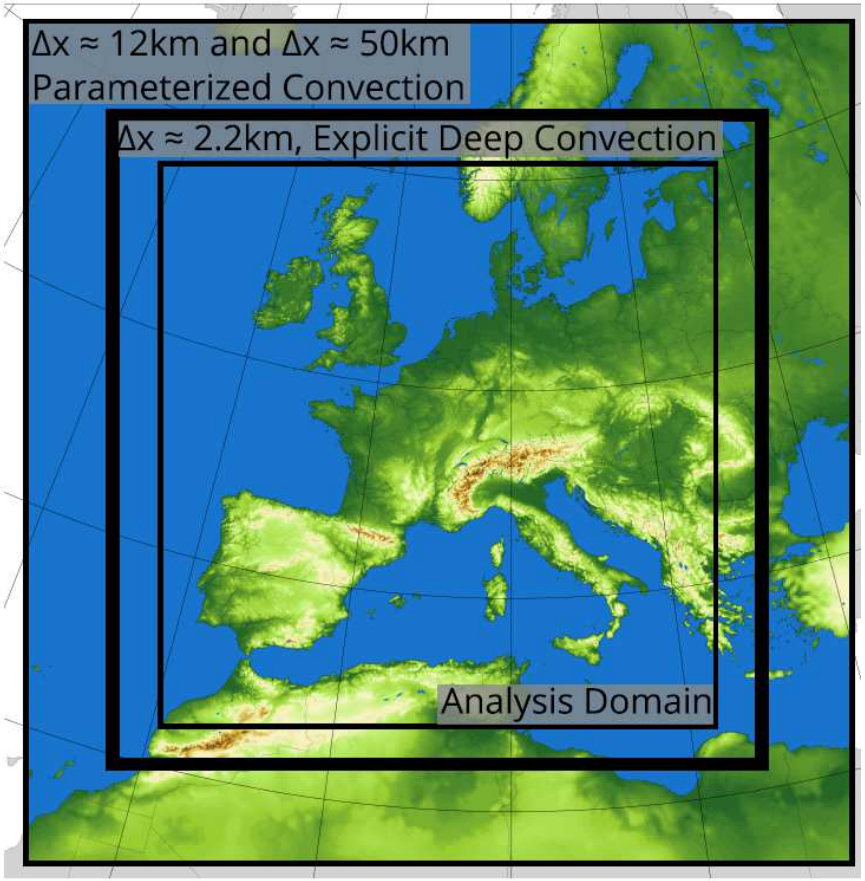


Switch to single precision

- 30% gain in BUs
- 30 → 21 minutes; 16 → 20 members

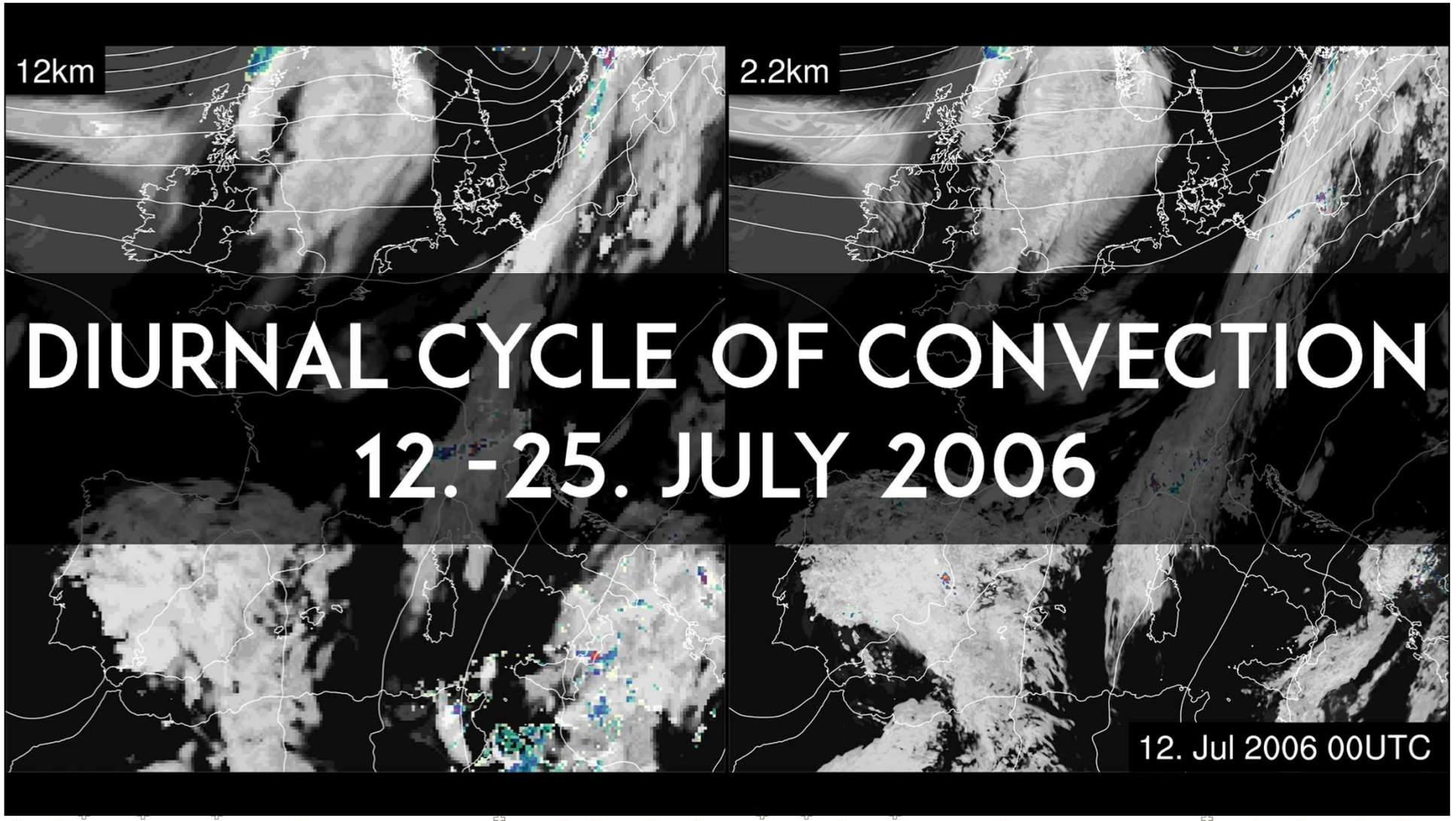
European-scale multi-year convection-resolving climate simulations

- COSMO Full-GPU-prototype based on v4.19 (Fuhrer et al., 2014)
- 1536x1536x60 grid points, 2.2 km grid spacing, $\Delta t = 20s$
- Period: 1999-2008
- Driven by ECMWF ERA-Interim reanalysis
- Calibration following Bellprat et al. (2016)
- Asymptotic turbulent length scale from Baldauf et al. (2011): 60 m

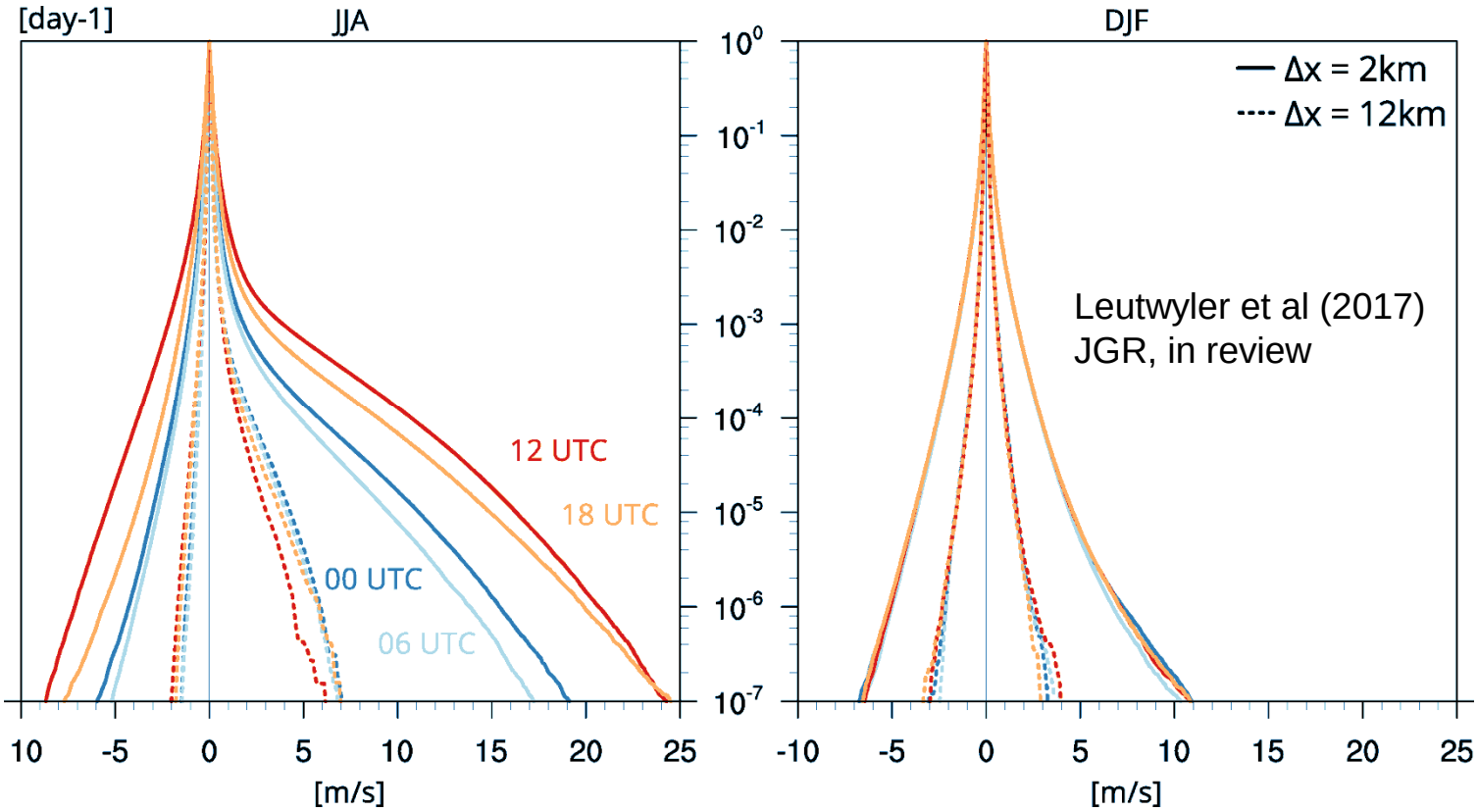


D. Leutwyler, PhD Thesis, ETHZ, 2016

Summer convection



Diurnal Cycle of Vertical Wind on 500 hPa



Peak over threshold, 500 hPa vertical wind, normalized, land-only

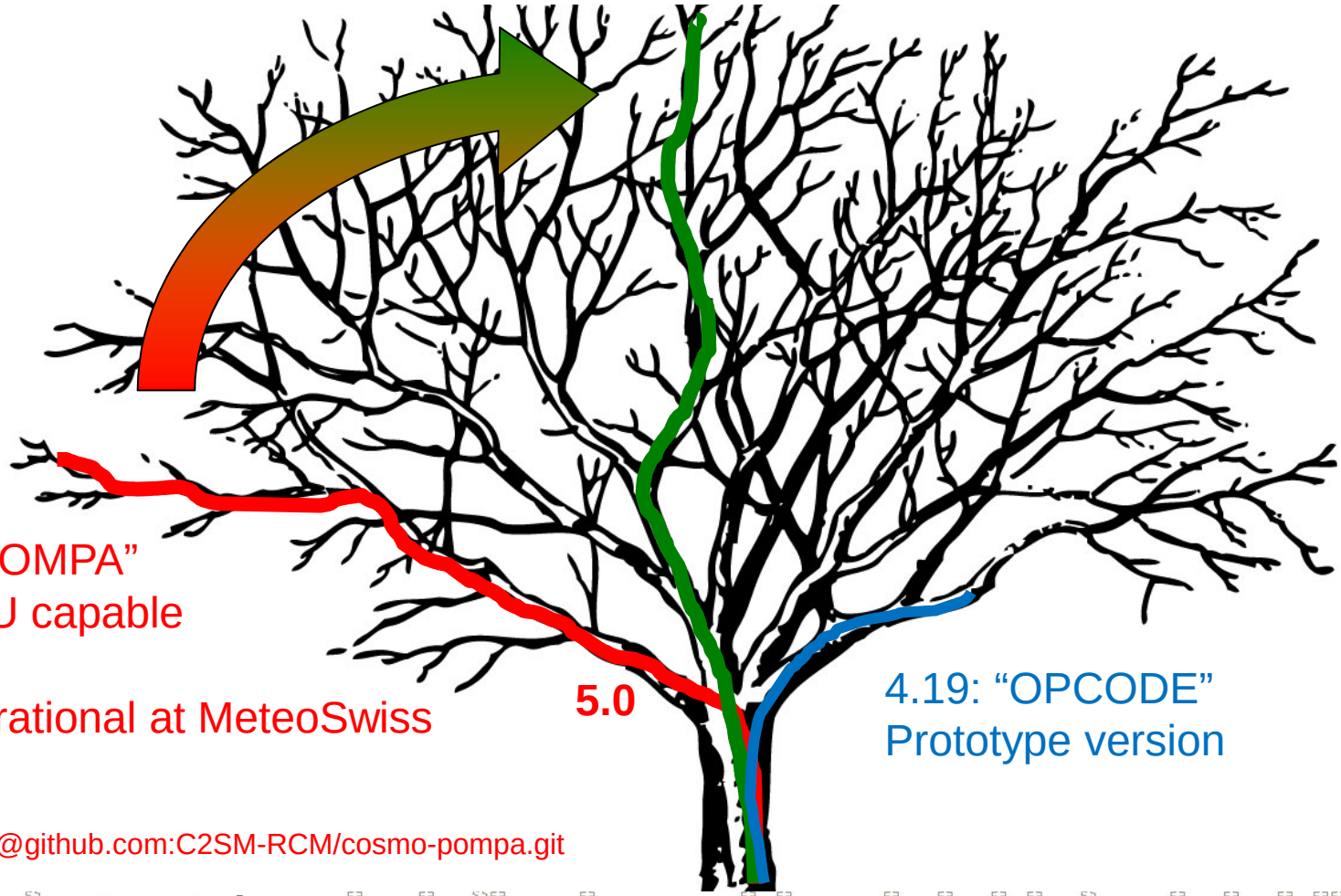
=> Increase of vertical wind with higher resolution

Model development : where are we ?

5.5: C++ dycore available for CPU only usage

5.X: Official version with full GPU-capability

Plan : current plan for official release September 2017



5.0+ “POMPA”
full GPU capable version
- Operational at MeteoSwiss

4.19: “OPCODE”
Prototype version

Github : git@github.com:C2SM-RCM/cosmo-pompa.git

Related projects

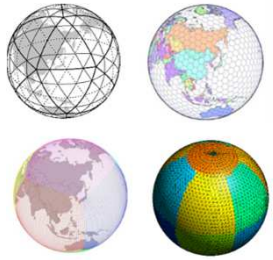
- CLAW
  CSCS,
  IAC (U. Lohmann)

```
SUBROUTINE inv_th(pclc,pca1, …)
  INTEGER:: kilsd

  !$acc parallel
  !$acc loop collapse(3)
  !$claw loop-interchange (k,i,j)
  DO i=istart,iend
    DO j=jstart,jend
      DO k=kstart,kend
        ! Computation is done here
      END DO
    END DO
  END DO
  !$acc end parallel

END SUBROUTINE inv_th
```

Optimization and performance portability using directives

https://github.com/C2SM-RCM/claw-compiler

- GridTools
  (PASC)
  Collaboration :
  CSCS, ECMWF, RIKEN

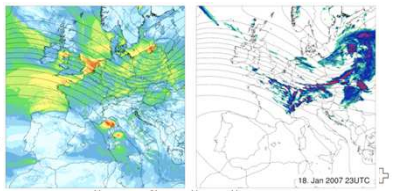


New library to replace STELLA supporting global models (IFS, ICON,…) and additional functions

- H2020 ESCAPE
  ECMWF

Energy-efficient Scalable Algorithms for Weather Prediction at Exascale

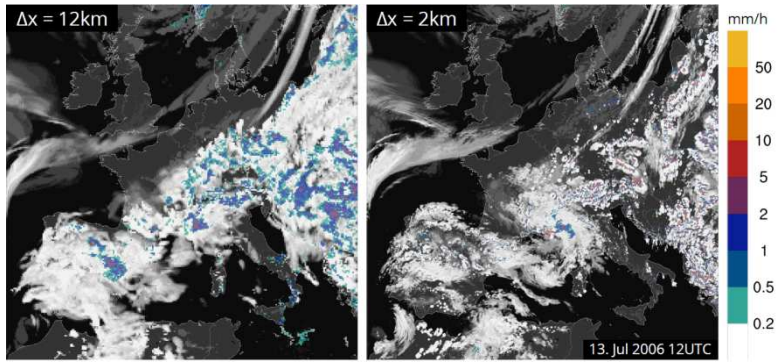
- crClim



Climate simulations, ETHZ

Summary

- About 4x was gained by software refactoring moving to GPUs as compare to traditional CPUs
- The new code version can be run in single precision
- Several projects already use for production these new developments
- The GPU branch is being merged to the official COSMO code and will be available in 2017.



- Info : training for compiling and using the C++ dycore will be given at the COSMO/CLM/ICON/ART-Training-Course 2017


THE END

Results

	Piz Dora	Piz Kesch	Factor
Energy per member	10 kWh	2.1 kWh	**4.8 x**
Time with 8 sockets per member	3.9 h	1.0 h	**3.9 x**
Cabinets required to run ensemble at required time-to-solution	1.4	0.38	**3.8 x**

Increase of x40 in computational cost of operational setup

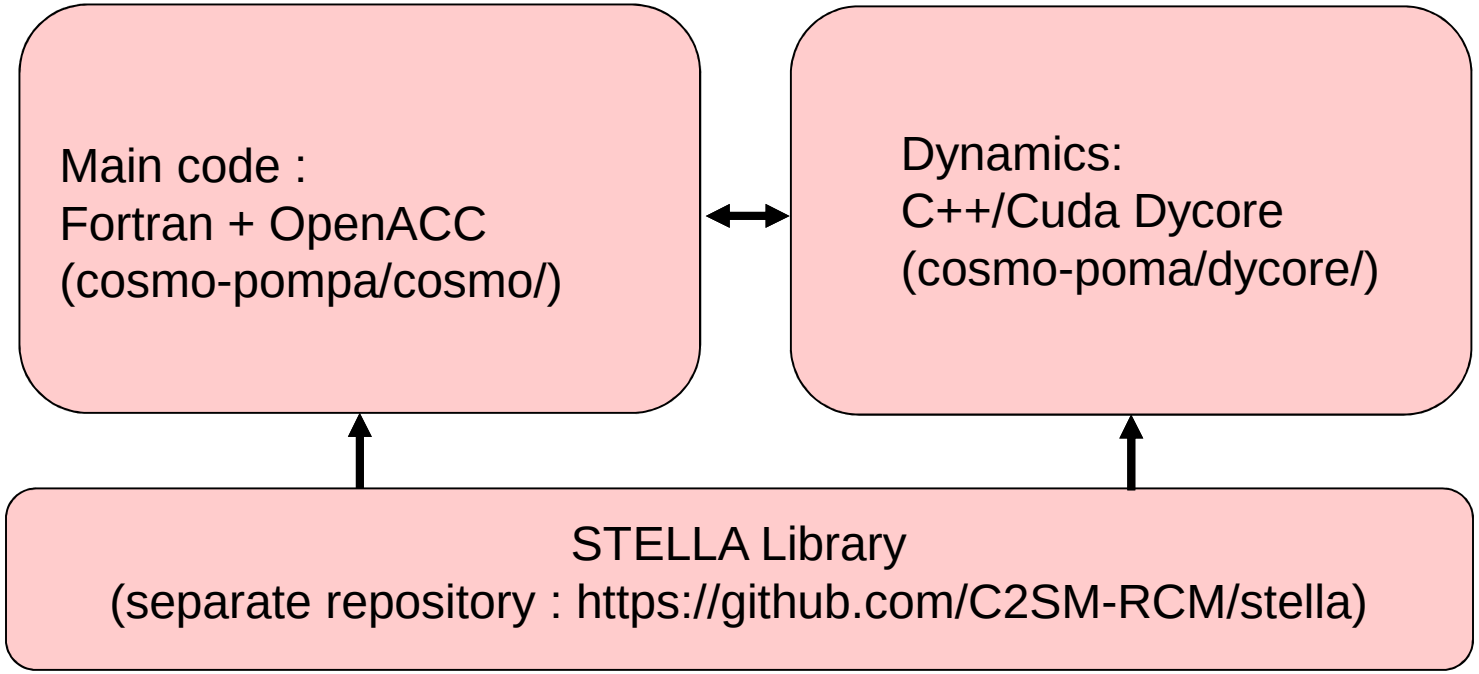
Key ingredients

- Processor performance (Moore's law) ~2.8 x
- Code refactoring and port to GPUs ~3.9 x
- Increase utilization of system ~2.8 x
- Increase in number of sockets ~1.3 x
- Target system architecture to application

≈ 40x

Image: Cray

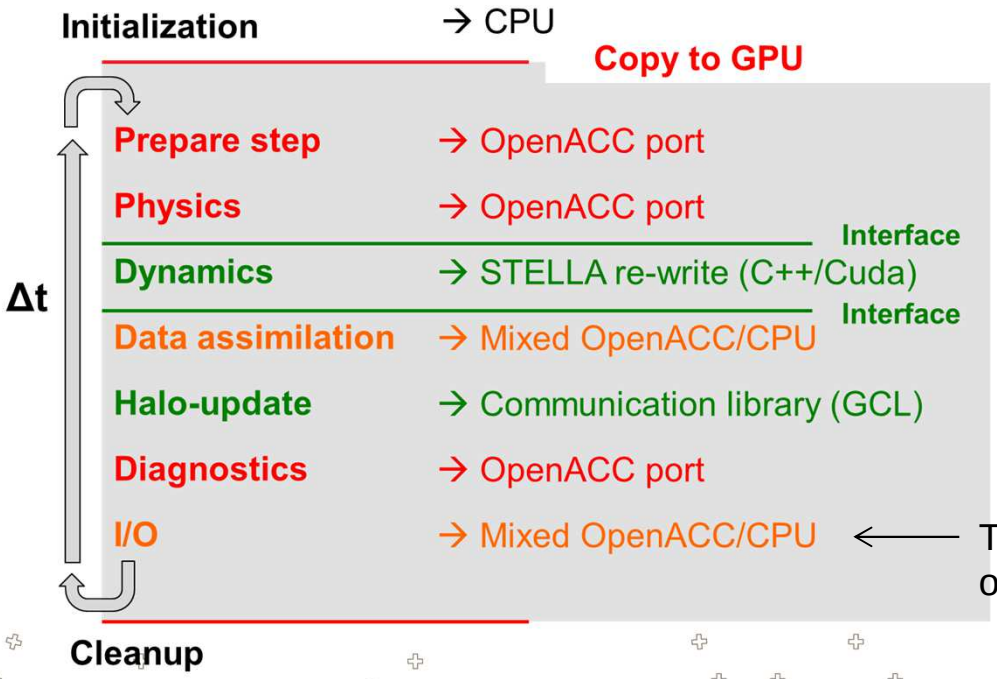
COSMO on GPU



- The GPU version requires to compile the 3 components: STELLA, Dycore and the main Fortran code

The COSMO model on GPU

- Take advantage of the high computational capacity of GPUs
- Low compute intensity : avoid GPU-CPU data transfer
- Full GPU port strategy : all computations on the GPU



Note :
Start replacement of Stella with Gridtools in 2017

Transfer to CPU on I/O step